FILTER CARTRIDGE AND PROCESS FOR PRODUCING THE SAME

FIELD OF THE INVENTION

The present invention relates to a filter cartridge and a process for producing the same, specifically to a cylindrical filter cartridge which is prepared by winding a non-woven fabric strip comprising thermoplastic fibers on a perforated cylinder in a twill form and which is excellent in a liquid-passing property, a filter life and stability of a filtering accuracy, and a process for producing the same.

BACKGROUND OF THE INVENTION

Various filters for clarifying a fluid are presently developed and produced. Among them, cartridge-type filters (hereinafter called filter cartridges) are widely used in the industrial field, for example, for removing suspended particles in industrial liquid materials, removing cakes flowing out of a cake filtering apparatus and clarifying industrial water.

Several kinds of structures of a filter cartridge have so far been proposed. The most typical one is a bobbin winder-type filter cartridge, which is a cylindrical filter cartridge prepared by winding a spun yarn as a filter material on a perforated cylindrical core in a twill form and then fluffing the spun yarn. This type has long been used due to inexpensiveness and easiness in production.

Another type of structure includes a non-woven fabric-laminated type filter cartridge. This is a cylindrical filter cartridge prepared by winding several kinds of non-woven fabrics such as a carding non-woven fabric stepwise and concentrically on a perforated cylindrical core. A recent advanced technique in a non-woven fabric production has allowed some of them to be put to practical use.

However, the above-mentioned filter cartridges have several defects. For example, in the bobbin winder-type filter cartridge for trapping foreign matters by means of fluffs of fluffed spun yarns and also in gaps of the spun yarns, it is difficult to control the size and form of the fluffs and gaps. This limits size and amount of the foreign matters that can be trapped. Further, constitutional fibers of a spun yarn, which is made from short fibers, fall away when fluid flows onto the filter cartridge.

Furthermore, in producing a spun yarn, a trace amount of a surfactant is often applied onto a surface of material short fibers to prevent the short fibers from sticking to a spinning machine by electrostatic charge or the like. Filtering a liquid by means of a filter cartridge using surfactant-coated spun yarns may bring adverse effects on the cleanness of liquid, such as foaming of the liquid, and increase in TOC (total organic carbon), COD (chemical oxygen demand) and the electric conductivity. In addition, a spun yarn is produced by spinning short fibers as already mentioned, for which at least two steps of forming and

spinning short fibers are required. Thus, use of the spun yarn will sometimes increase a price of the product.

A performance of a non-woven fabric-laminated type filter cartridge depends on the non-woven fabric used. A non-woven fabric is produced mostly by a method in which short fibers are confounded by means of a carding machine or an air laid machine and then subjecting them, if necessary, to heat treatment by means of a hot-air heater or a heating roll, or a method in which a non-woven fabric is directly prepared, such as a melt blowing method and a spun bonding method. However, any machines used for producing non-woven fabrics, such as a carding machine, an air laid machine, a hot-air heater, a heating roll, a melt blowing machine and a spun bonding machine, may cause, for example, uneven basis weights of a non-woven fabric in a lateral direction of a machine. Accordingly, a filter cartridge of poor quality will be produced. Also, use of a more advanced manufacturing technique to avoid such unevenness sometimes raises the production cost. Moreover, production of one kind of non-woven fabric-laminated type filter cartridges needs two to six kinds of non-woven fabrics, and different non-woven fabrics are needed depending on the kind of a filter cartridge. Thus, the production cost will increase in some cases.

Several methods have been proposed in order to solve such problems of conventional filter cartridges. For example, Japanese Utility Model Publication No. 6-7767

proposes a filter cartridge in which a filter material obtained by squashing a tape-shaped paper having porosity while twisting, thereby squeezing it to control a diameter thereof to about 3 mm is wound around a porous internal cylinder in a close twill. This method is advantageous in that a winding pitch can be gradually increased from the porous internal cylinder toward the outside. However, the filter material needs to be squashed and squeezed, so that foreign matters are trapped primarily between the winding pitches of the filter material. Accordingly, it is less expected to trap foreign matters by the filter material itself as is the case of a conventional bobbin winder type filter using spun yarns which traps foreign matters by means of fluffs. This blocks the surface of the filter to shorten the filter life or brings about the poor liquid-passing property in a certain case.

JP-A 1-115423 proposes a filter in which strings obtained by slitting a cellulose spun bonded non-woven fabric into strips and passing them through narrow holes to twist them are wound around a bobbin having a lot of drilled pores. It is considered that this method shall make it possible to prepare a filter having a higher mechanical strength and being free of dissolution in water and elution of a binder, as compared with a conventional roll tissue filter prepared by winding tissue paper in a roll form, which is produced from α-cellulose prepared by refining a coniferous pulp.

However, the cellulose spun bonded non-woven fabric used for this filter has a papery form and thus a too high rigidity, so that it is less expected to trap foreign matters by the filter material itself as is the case of a conventional bobbin winder type filter using spun yarns which traps foreign matters by means of fluffs. Further, the cellulose spun bonded non-woven fabric is liable to swell in a liquid due to its papery form. Swelling may bring about various problems such as a decrease in a filter strength, a change in a filtering accuracy, a deterioration in a liquid-passing property, a reduction in a filter life and the like. Adhesion at fiber intersections of the cellulose spun bonded non-woven fabric are mostly conducted by a certain chemical treatment. Such adhesion is often unsatisfactory, causing a change in a filtering accuracy or falling of fiber chips, so that a stable filtering performance is difficult to achieve.

Further, JP-A 4-45810 proposes a filter prepared by winding a slit non-woven fabric comprising composite fibers in which 10% by weight or more of structural fibers is divided ones of 0.5 denier or less on a porous core cylinder to provide the fiber density of 0.18 to 0.30. This method is advantageously used to trap fine particles contained in a liquid by means of fibers having a high fineness. However, in order to divide the composite fibers, a stress needs to be applied using, for example, high-pressure water, and it is difficult to evenly divide the

fibers all over the non-woven fabric by means of high-pressure water processing. If not evenly divided, there occurs a difference in a trapped particle diameter between a well-divided portion and an insufficiently divided portion of the non-woven fabric, and this may lower the filtering accuracy. Further, the stress applied for dividing sometimes lowers a strength of the non-woven fabric, and this may cause reduction of the resulting filter strength and frequent deformation of the filter during use; or possible change of the void ratio of the filter may reduce the liquid-passing property.

Further, the reduced strength of the non-woven fabric makes it difficult to control a tension in winding around a porous core cylinder, and hence the difficulty in exact control of the void rate may arise. Further, a spinning technique required for producing easily divisible fibers and an increased operation cost in producing thereof lead to an increased production cost of the filter. Such a filter would be usable in a certain field such as the pharmaceutical industry and the electronic industry which require a high filtering performance, if the above mentioned problems of the filtering performance are solved. However, such a filter is considered to be difficult to use in cases in which inexpensive filters are requested such as the filtering of swimming pool water and a plating liquid for the plating industry.

An object of the present invention is to provide a cylindrical filter cartridge which is excellent in a liquid-passing property, a filter life and stability of a filtering accuracy.

An object of the present invention is to solve the problems described above. It has been found, as a result of investigations, that a cylindrical filter cartridge which is excellent in a liquid-passing property, a filter life and a stability of a filtering accuracy can be obtained by winding a long fiber non-woven fabric comprising thermoplastic fibers on a perforated cylinder in a twill form.

SUMMARY OF THE INVENTION

The present inventors have conducted intensive researches and, as a result, found that the problems described above can be solved by a cylindrical filter cartridge, which is prepared by winding a non-woven fabric strip on a perforated cylinder in a twill form, in which the strip is a long fiber non-woven fabric and/or a melt blown non-woven fabric comprising thermoplastic fibers and an airflow amount (air permeability) is specially related to a basis weight; or by specifying a number of winding in producing the filter cartridge. This finding has led to the present invention.

The present invention is composed of:

(1) A filter cartridge which is prepared by winding a non-woven fabric strip comprising a thermoplastic fiber

around a perforated cylinder in a twill form, wherein the non-woven fabric strip satisfies the following equation (A):

$$\log_{10} Y < 3.75 - 0.6 (\log_{10} X) \qquad (A)$$

wherein X ($cm^3/cm^2/sec$) is an airflow amount of the non-woven fabric strip measured in accordance with JIS L 1096-A (1990), and Y (g/m^2) is a basis weight thereof.

(2) A filter cartridge which is prepared by winding a long fiber non-woven fabric strip comprising a thermoplastic fiber around a perforated cylinder in a twill form, wherein the non-woven fabric strip satisfies the following equation (B):

$$\log_{10} Y < 3.75 - 0.75 (\log_{10} X) \qquad (B)$$

wherein X ($cm^3/cm^2/sec$) is an airflow amount of the non-woven fabric strip measured in accordance with JIS L 1096-A (1990), and Y (g/m^2) is a basis weight thereof.

(3) A filter cartridge which is prepared by winding a non-woven fabric strip comprising a thermoplastic fiber around a perforated cylinder in a twill form, wherein in winding in a twill form, a number (W) of winding the non-woven fabric strip from one end to the other end in a longitudinal direction of the perforated cylinder is one to 10 per a length of 250 mm in the perforated cylinder.

(4) The filter cartridge as described in the item (3), wherein when a 2-fold value (2W) of the winding number (W) is represented by a fraction having a denominator of two figures or less which is a non-reducible approximate value, the denominator is 4 to 40.

(5) The filter cartridge as described in any one of the items (1) to (3), wherein at least a part of fiber intersections of the non-woven fabric strip is thermally bonded.

(6) The filter cartridge as described in any one of the items (1) to (3), wherein the non-woven fabric strip has a width of 0.5 to 40 cm.

(7) The filter cartridge as described in any one of the items (1) to (3), wherein a product of a width (cm) and a basis weight (g/m^2) of the non-woven fabric strip is 10 to 200.

(8) The filter cartridge as described in any one of the items (1) to (3), wherein the non-woven fabric strip has a thickness of 0.02 to 1.20 mm.

(9) The filter cartridge as described in any one of the items (1) to (3), wherein the non-woven fabric strip is thermal compression bonded by means of a heat embossing roll having an embossing area rate of 5 to 25%.

(10) The filter cartridge as described in any one of the items (1) to (3), wherein the filter material of the filter cartridge has a void rate of 65 to 85%.

(11) The filter cartridge as described in the item (1) or (3), wherein the non-woven fabric strip is of a long fiber non-woven fabric.

(12) The filter cartridge as described in the item (11), wherein the long fiber non-woven fabric is produced by a spun bonding method.

(13) The filter cartridge as described in the item (1) or (3), wherein the non-woven fabric strip is of a melt blown non-woven fabric.

(14) The filter cartridge as described in any one of the items (1) to (3), wherein the thermoplastic fiber is a composite fiber comprising a low melting resin and a high melting resin, a difference of the melting points between these resins being 10°C or more.

(15) The filter cartridge as described in any one of the items (1) to (3), wherein the thermoplastic fiber is a fiber formed from at least one thermoplastic resin selected from the group consisting of a polyester resin, a polyamide resin, a polyethylene resin and a polypropylene resin.

(16) A process for producing a filter cartridge, which comprises winding a non-woven fabric strip comprising a thermoplastic fiber around a perforated cylinder in a twill form, wherein the non-woven fabric strip satisfies the following equation (A):

$$\log_{10} Y < 3.75 - 0.6 (\log_{10} X) \qquad (A)$$

wherein X ($cm^3/cm^2/sec$) is an airflow amount of the non-woven fabric strip measured in accordance with JIS L 1096-A (1990), and Y (g/m^2) is a basis weight thereof.

(17) A process for producing a filter cartridge, which comprises winding a non-woven fabric strip comprising a thermoplastic fiber around a perforated cylinder in a twill form, wherein in winding in a twill form, a number (W) of winding the non-woven fabric strip from one end to the other

end in a longitudinal direction of the perforated cylinder is one to 10 per a length of 250 mm in the perforated cylinder.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a conceptual diagram of a spun bonded non-woven fabric.

Fig. 2 is a conceptual diagram of a short fiber non-woven fabric.

Fig. 3 represents the equation (A) showing a relation of a basis weight to an airflow amount of the non-woven fabric.

Fig. 4 is an illustration of winding a non-woven fabric strip as it is, without processing.

Fig. 5 is an illustration of winding a non-woven fabric strip with twisting.

Fig. 6 is an illustration of winding a non-woven fabric strip with traversing.

Fig. 7 is an illustration of trapping foreign matters by means of an embossing pattern of a non-woven fabric.

Fig. 8 is a perspective of the filter cartridge according to the present invention.

Explanation of Codes

1: Long fiber constituting spun bonded non-woven fabric

2: Foreign matters

3: Bobbin

4: Perforated cylinder

5: Traverse guide

6: Non-woven fabric strip or converged matter thereof

7: Filter cartridge

8: Part where strong thermal compression bonding by an embossing pattern is applied.

9: Part where only weak thermal compression bonding by deviating from an embossing pattern is applied

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The embodiment of the present invention shall be explained below in detail.

The filter cartridge of the present invention is prepared by winding a non-woven fabric strip comprising a thermoplastic fiber on a perforated cylinder in a twill form.

In the present invention, the non-woven fabric strip means a non-woven fabric having a narrow width, which is prepared by slitting (cutting) a wide non-woven fabric or produced directly in a narrow width. It is preferable that a wide non-woven fabric is slit in order to obtain the stable quality at low cost. An optimum width and basis weight of a non-woven fabric to be used shall be described later.

In the present invention, the thermoplastic fiber means a fiber produced from a thermoplastic resin. All thermoplastic resins capable of being melt-spun can be used

for the thermoplastic resin used in the present invention. Examples include polyethylene resins such as low density polyethylene, high density polyethylene and linear low density polyethylene; polypropylene resins such as polypropylene and copolymerized polypropylene (for example, binary or multi-component copolymers comprising propylene as a primary component with ethylene, butene-1, 4-methylpentene-1 and the like); other polyolefin resins than the above polyethylene and polypropylene resins; polyester resins such as polyethylene terephthalate, polybutylene terephthalate and low melting polyesters copolymerized with addition of isophthalic acid besides terephthalic acid as an acid component; polyamide resins such as nylon 6 and nylon 66; and thermoplastic resins such as polystyrene, polyurethane elastomers, polyester elastomers and polytetrafluoroethylene.

Functional resins can also be used so as to provide a filter cartridge with a biodegradability derived from biodegradable resins such as a lactic acid base polyester. Further, polyolefin resins and polystyrene resins which can be polymerized using metallocene catalysts are preferably used for a filter cartridge, taking advantage of the characteristics of metallocene resins such as improvements in a strength of a non-woven fabric and a chemical resistance, and a reduction in a production energy. Also, those resins may be blended for use in order to control a heat adhesion property and a rigidity of a non-

woven fabric. When a filter cartridge is used for filtering an aqueous solution of room temperature, polyolefin resins such as polypropylene and polyethylene are preferably used from the viewpoints of a chemical resistance and a cost. When used for a solution of a relatively high temperature, polyester resins and polyamide resins are preferred.

These thermoplastic resins can be blended, if necessary, with publicly known additives.

The non-woven fabric strip used in the present invention is preferably a long fiber non-woven fabric or a melt blown non-woven fabric, and the resulting filter cartridge reduces a risk that fibers fall off and are mixed in a filtrate when used for filtering.

The long fiber non-woven fabric or melt blown non-woven fabric described above can be used separately as a non-woven fabric strip or in the form of a laminated non-woven fabric of the both.

In the filter cartridge of the present invention, the melt blown non-woven fabric as the non-woven fabric strip has a higher fineness than that of the long fiber non-woven fabric, and the texture thereof can easily be homogenized. Accordingly, the resulting filter cartridge can be improved in a filtering accuracy.

An average fiber diameter of the above melt blown non-woven fabric varies depending on uses of the filter cartridge and kinds of the resin, and is 0.5 to 1000 μm, preferably 1 to 50 μm. If the average fiber diameter is

less than 0.5 μm, it is difficult to produce the non-woven fabric, which may result in a high-cost filter cartridge. On the other hand, the average fiber diameter exceeding 1000 μm expands a distribution of the fiber diameter and deteriorates a texture of the resulting non-woven fabric. Further, the average fiber diameter exceeding 50 μm may allow the adjacent fibers to bond each other by remaining heat, but it makes no difference especially as long as it does not prevent the effects of the present invention.

The non-woven fabric strip used in the present invention is preferably a long fiber non-woven fabric, a melt blown non-woven fabric or a laminated non-woven fabric thereof, in which at least a part of fiber intersections thereof is thermally bonded. Among them, preferred is the long fiber non-woven fabric in which at least a part of fiber intersections thereof is thermally bonded.

In particular, a non-woven fabric obtained by a spun bonding method is preferred as the long fiber non-woven fabric described above. The spun bonding method is a non-woven fabric production technique in which a thermoplastic fiber discharged from a nozzle is sucked and drawn by an air gun, spread on a conveyor and then thermally bonded. The long fiber non-woven fabric comprising thermoplastic fibers produced by the spun bonding method has a fiber direction aligned along a machine direction as shown in Fig. 1, so that a hole constituted by fibers 1 becomes long and narrow, and a maximum size of the passing particle 2 is

rather small. In contrast with this, a non-woven fabric comprising short fibers obtained by a carding method and the like has a fiber direction not fixed as shown in Fig. 2, so that a hole constituted by fibers 1 has a shape close to a circle or a square, and a maximum size of the passing particle 2 is larger than that of a long fiber non-woven fabric produced by the spun bonding method, even the two has the same fiber diameter and void rate.

In the present invention, other fibers than the thermoplastic fiber, for example, cotton, glass fibers and metallic fibers can be used in combination as structural fibers of the non-woven fabric strip as long as they do not impair a filter life, a liquid-passing property and the functions such as preventing matters from falling off the filter cartridge which are characteristics of the present filter cartridge.

In the non-woven fabric strip used for producing the filter cartridge which is the first embodiment of the present invention, an airflow amount X ($cm^3/cm^2/sec$) and a basis weight Y (g/m^2) which are measured by a JIS L 1096-A method satisfy the following equation (A) by bonding the fiber intersections thereof.

$$\log_{10} Y < 3.75 - 0.6 (\log_{10} X) \qquad (A)$$

The filter cartridge of the present invention which is prepared by winding the non-woven fabric strip around a perforated cylinder in a twill form exhibits an excellent filtering accuracy.

A relation of the equation (A) is shown in Fig. 3. The equation (A) represents a shaded area in Fig. 3 and exhibits a basis weight range corresponding to the respective airflow amounts of the non-woven fabric strip. When the airflow amount and the basis weight do not have a relation represented by the shaded area, it means that the basis weight is too large, and a rigidity of the non-woven fabric strip becomes too high, so that it is difficult to minutely wind the non-woven fabric strip around the perforated cylinder, and the resulting filter cartridge may have a reduced filtering accuracy.

If the production process of the present invention is a spun bonding process in which a non-woven fabric is prepared directly from a formed fiber, the resulting filter cartridge reduces a risk that the fibers fall off and are mixed in the filtrate when used for filtering. Further, it is relatively low in cost, and therefore, it is preferable.

In the second embodiment of the present invention, the non-woven fabric strip is a long fiber non-woven fabric, and the airflow amount X ($cm^3/cm^2/sec$) and the basis weight Y (g/m^2) satisfy the following equation (B). In such a case, the filter cartridge is excellent in a non-woven fabric strength and a property of preventing the fibers from falling off the filter cartridge, and therefore it exhibits a particularly excellent filtering accuracy.

$$\log_{10} Y < 3.75 - 0.75 (\log_{10} X) \qquad (B)$$

Next, a method for winding the non-woven fabric strip around a perforated cylinder shall be explained. One example of the processes is shown in Fig. 4. A winder conventionally used for a bobbin winder type filter cartridge can be used for the winding machine. A perforated cylinder 4 having a diameter of about 10 to 40 mm and a length of 100 to 1000 mm is installed to a bobbin 3 of this winder. A non-woven fabric strip 6 passes through a yarn passage and a hole of a traverse guide 5 of the winder to be converged and wound around the perforated cylinder one to two times. The perforated cylinder may be thermally bonded to an end part of the non-woven fabric strip in order to accurately wind the strip. The yarn passage of the winder is waved in each longitudinal direction in a twill form by means of the traverse guide 5 disposed parallel to the bobbin, so that the non-woven fabric strip is wound around the perforated cylinder in a twill form by rotation of the bobbin, whereby a filter cartridge 7 is produced. A diameter of the hole disposed in the traverse guide 5 varies depending on a basis weight and a width of the non-woven fabric strip used and falls preferably in a range of 3 to 10 mm. If this diameter is less than 3 mm, a friction between the non-woven fabric strip and the hole is increased, so that the winding tension becomes too high. On the other hand, the value larger than 10 mm may not render the converging size of the non-woven fabric stabilized. Various traverse guides having a narrow hole can be used for the

traverse guide 5. For example, those in an almost circular form, an almost elliptical form and an almost flat form can be used. Further, those having an aperture part at one end of a narrow hole can be used as well.

The perforated cylinder functions as a core of a filter cartridge, and the material and the form thereof shall not specifically be restricted as long as it has a strength which is endurable to external pressure applied in filtering and the pressure loss is not markedly high. It may be, for example, an injection-molded article obtained by processing polyethylene or polypropylene into a net type cylinder as is the case with a core used for a conventional filter cartridge or ones obtained by processing ceramics and stainless steel in the same manner. Alternatively, other filter cartridges such as a filter cartridge subjected to pleat-folding processing and a filter cartridge of a non-woven fabric-winding type can be used as a perforated cylinder.

The winding conditions in this case can be set up according to those in producing a conventional bobbin winder type filter cartridge. Initial speed of the bobbin may be set to, for example, 1000 to 2000 rpm, and the feeding speed may be controlled to apply a tension in winding the non-woven fabric. The void rate of the filter cartridge can be changed by the tension in this case.

On the other hand, this non-woven fabric strip can be twisted and then wound. One embodiment of the production

process is shown in Fig. 5. Also in this case, a winder conventionally used for a bobbin winder type filter cartridge can be used for the winding machine. The non-woven fabric becomes apparently thick by twisting, and therefore a traverse guide 5 has preferably a larger hole diameter than that in the case of Fig. 4. By twisting a non-woven fabric, an apparent void rate of the non-woven fabric can be changed depending on a twisting number per unit length or a twisting strength, so that the filtering accuracy can be controlled. The twisting number in this case falls preferably in a range of 50 to 1000 times per meter of the non-woven fabric strip. If this value is smaller than 50 times, the twisting effect is scarcely obtained. On the other hand, the value larger than 1000 times will provide the filter cartridge produced with a inferior liquid-passing property. Accordingly, both are not preferred.

It is more preferred to converge the non-woven fabric strip by any method and then wind it around a perforated cylinder. Such a method include one in which the non-woven fabric strip may be passed merely through a small hole to be converged or one in which the cross-sectional form of the non-woven fabric strip may be pre-molded by means of a pleat-forming guide and then passed through a small hole to be processed into a pleated matter. Use of the latter method makes it possible to control a ratio of a traversing speed of the traverse guide to a rotating speed

of the bobbin to change the winding pattern, so that filter cartridges having various performances can be produced from the same kind of the non-woven fabric strip.

One embodiment of a production process in which the non-woven fabric is passed merely through a small hole for converging the strip is shown in Fig. 6. Also in this case, a winder conventionally used for a bobbin winder type filter cartridge can be used for the winding machine. In Fig. 6, the hole of a traverse guide 5 turned into a small hole, thereby converging the non-woven fabric strip, but a guide of a small hole may be provided at a yarn passage in front of the traverse guide 5. The diameter of the small hole varies depending on the basis weight and the width of the non-woven fabric used and falls preferably in the range of 3 to 10 mm. If this diameter is smaller than 3 mm, a friction between the non-woven fabric and the small hole is increased, so that the winding tension becomes too high. On the other hand, the value larger than 10 mm may not render the converging size of the non-woven fabric stabilized.

Further, when producing the above non-woven fabric strip-converged matter, granular activated carbon or ion exchange resins may be present as long as they do not damage the effects of the present invention. In this case, in order to fix granular activated carbon or ion exchange resins, they may be bonded by means of a suitable binder either prior to or after converging the non-woven fabric strip or processing it into a pleated matter, or they may be

first added and then thermally bonded to the structural fibers of the non-woven fabric by heating.

The yarn passage of the winder is waved in twill form by means of a traverse cam disposed parallel to the bobbin, so that the non-woven fabric strip is wound around the perforated cylinder while waving in a twill form. The winding conditions in this case can be set up according to those in producing a conventional bobbin winder type filter cartridge. Initial speed of the bobbin may be set to, for example, 1000 to 2000 rpm, and the feeding speed may be controlled to apply a tension in winding the non-woven fabric. The void rate of the filter cartridge can be changed by the tension in this case.

Further, the tension in winding is controlled to make the void rate of an internal layer small, and the void rate of an intermediate layer to an external layer gradually large as the non-woven fabric is wound around. In particular, when the non-woven fabric strip is first formed into the pleated matter and then is wound around the perforated cylinder, there can be provided a filter cartridge having an ideal filtering structure owing to a difference in rough and dense structures formed in the external layer, the intermediate layer and the internal layer in combination with a deep layer-filtering structure formed by the pleats of the pleated matter.

The filtering accuracy can be changed by controlling a ratio of the traversing speed of the traverse

cam to the rotating speed of the bobbin, thereby changing a number (hereinafter referred to as a winding number and represented by W) of winding the non-woven fabric strip around the perforated cylinder from one end to the other end in a longitudinal direction when winding the non-woven fabric strip in a twill form. That is, the winding number means a rotation number of the bobbin 3 while the traverse guide 5 moves from one end to the other end of the perforated cylinder 4 in a longitudinal direction. Accordingly, a value of W is not necessarily a natural number. The winding number should be very accurate, and therefore, a moving distance of the traverse guide has to be geared to a rotation number of the bobbin so that this value should not get out of order.

In the filter cartridge of the present invention, a winding number W is 1 to 10, preferably 2 to 8 and more preferably 3 to 5 per 250 mm of the perforated cylinder used for the filter cartridge. If this value is less than one, an angle of traversing becomes too large, and therefore the non-woven fabric strip is liable to get out of the perforated cylinder. On the other hand, if this value exceeds 10, an angle of traversing becomes too small, and the non-woven fabric strip is liable to get out of the perforated cylinder also in this case. Further, if the value deviates from the range of 1 to 10, an initial trapped particle diameter becomes extremely large, resulting in an inadequate filter cartridge.

A relation of the winding number to the filtering accuracy is well known in the case of a wound filter in which a spun yarn is used as a filtering material. In a conventional wound filter in which a spun yarn is used, a winding yarn (that is, a spun yarn) generally has a circular cross-sectional form, and a yarn diameter thereof is about 3 mm at the largest. Thus, the winding number and the pitch of the yarn in winding in a twill form can be represented by the following equations (1) and (2):

$$2 \times W = 2 \times W_0 \pm 1/N \qquad (1)$$

$$N = T/W_0/P \qquad (2)$$

wherein W is a winding number; W_0 is a natural number approximate to the winding number W; N is an ordered number; T is a traverse width; and P is a pitch of the yarn. Among the above variables, W_0 and N are natural numbers, and W, P and T are arbitrary positive numbers. In general, as the pitch of the yarn becomes smaller, the wind filter having a finer accuracy is prepared. This equation can be applied to a yarn other than a spun yarn, for example, a split yarn.

On the other hand, in the filter cartridge of the present invention, the non-woven fabric strip is used as a filter material in place of a spun yarn, and therefore the equations (1) and (2) cannot be applied as they are. The non-woven fabric is converged in winding as described above, so that a thickness of the yarn becomes far large as compared with that of a conventional spun yarn. Accordingly, even if the conditions of the equations (1) and

(2) are satisfied, the yarns themselves are superposed and a filter cartridge having the intended accuracy is not obtained.

As the third embodiment of the present invention, we have found that a filter cartridge, which is prepared by winding a non-woven fabric strip around a perforated cylinder in a twill form, exhibits an excellent filtering performance when a denominator M_n is a specific value the winding number approximated by the following equation (3):

$$2 \times W \fallingdotseq X/M_n \qquad (3)$$

wherein X/M_n represent a non-reducible fraction, X and M_n are each independently natural numbers, and n represents a maximum figure of the number; for example, M_2 is an integer of 1 to 99.

In the present invention, when a 2-fold value (2W) of the winding number (W) is represented by an approximate fraction having a non-reducible denominator of two figures or less, M_2 in the equation (3), i.e., a value of the denominator is 4 to 40, preferably 5 to 20. As the value of M_2 becomes larger, the filter cartridge having a finer texture is prepared. If this value is less than 4, a texture of the resulting filter cartridge is roughened too much, and it is likely that a filter cartridge end face is not smooth. On the other hand, if the value of M_2 exceeds 40, a texture of the filter cartridge becomes too fine, and it is likely that the liquid-passing property is reduced and the filter life is shortened.

In this case, it is important that the value of 2W is approximate to a fraction having a denominator of a natural number of two figures or less. For example, when the winding number is 1.893, 2 × W is 3.786. When this 3.786 is approximated to a fraction having a denominator of one figure, it is 3 and 4/5 (this means a mixed fraction consisting of 3 and four fifths, and the same shall apply unless otherwise described). Accordingly, when the winding number is 1.893, M_1 is 5 which is the denominator of 3 and 4/5. Similarly, when 2W is approximated to a fraction having a denominator of two figures or less, a value thereof is 3 and 11/14, and therefore M_2 is 14 which is a denominator of 3 and 11/14. Similarly, when 2W is approximated to a fraction having a denominator of three figures or less, it is 3 and 393/500, and therefore M_3 is 500. Accordingly, in this case, a value of M_2 in the equation (3) is 14 which is the denominator when approximated to a fraction having a denominator of two figures. When 2W is approximated to a fraction having a denominator of two figures or less, 3 and 22/28 and 3 and 33/42 are also the most approximate values, but these number are reduced to 3 and 11/14, so that a value of M_2 is 14 in this case.

The value of M_2 described above is varied in a range of 4 to 40, whereby filter cartridges having various accuracies can be prepared even if the same non-woven fabric strip is used. Further, it can also be combined with a

method of varying a width, a basis weight or a fiber diameter of the non-woven fabric strip.

A deep layer-filtering structure of the filter cartridge can further be optimized by winding the non-woven fabric with M_2 set to a specific value until the major diameter becomes a certain degree, and by further winding the non-woven fabric with the value of M_2 changed.

In the filter cartridge of the present invention, the non-woven fabric strip is wound around the perforated cylinder 2 to form a filter cartridge having a major diameter 1.5 to 3 times as large as that of the perforated cylinder. Even when wound in the same winding number, a space between the non-woven fabric strips is varied depending on a major diameter of the perforated cylinder 4. A major diameter of the perforated cylinder 4 is usually decided according to use conditions, and the filtering performance is not controlled by a major diameter of the perforated cylinder 4. If the winding number is the same, as the major diameter of the filter cartridge becomes larger, the particle diameter of the initial particles trapped on the filter cartridge becomes smaller.

A fiber diameter of the long fiber used for the long fiber non-woven fabric described above varies depending on uses of the filter cartridge and kinds of the resin, and it is preferably in a range of 5 to 680 μm. If the fiber diameter exceeds 680 μm, it makes no difference between continuous yarns merely bound into a bundle and the long

fiber non-woven fabric. On the other hand, even if the fiber diameter is less than 5 µm, the resulting long fiber non-woven fabric can be used for a filter cartridge. However, when the long fiber non-woven fabric is a non-woven fabric prepared by a spun bonding method as described above (hereinafter referred to as a spun bonded non-woven fabric), spinning of fibers having a fiber diameter of less than 5 µm by the spun bonding method reduces a production efficiency and is not practical. The fiber diameter is more preferably 9 to 150 µm.

In the filter cartridge of the present invention, a non-woven fabric prepared by laminating a long fiber non-woven fabric and a melt blown non-woven fabric may be used for the non-woven fabric strip. In this case, it can make good use of both advantages of the long fiber non-woven fabric and the melt blown non-woven fabric. A particle-trapping performance of the filter cartridge is influenced a great deal by a fiber diameter of the melt blown non-woven fabric, and this is particularly preferred when preparing the filter cartridge with a high accuracy.

The laminating method shall not specifically be restricted. A fiber aggregate of the melt blown non-woven fabric and that of the long fiber non-woven fabric (long fiber web) may be produced respectively at different steps and then superposed, or alternatively, fibers may be melt-blown directly on the long fiber non-woven fabric or the long fiber web and laminated. Examples of combinations of

the fibers for the laminated non-woven fabric include two layers of melt blown fiber/long fiber, three layers of long fiber/melt blown fiber/long fiber, and three layers of melt blown fiber/melt blown fiber/long fiber which comprise two melt blown fibers having different fiber diameters.

In the present invention, yarns having different cross sections can be used. They can provide a filter cartridge having the same liquid-passing property and a higher accuracy, as compared with the fibers having a circular cross section, because an amount of trapped fine particles increases as a surface area of the filter becomes larger.

In the present invention, the thermoplastic resin used for producing the thermoplastic fiber can be blended with a hydrophilic resin such as polyvinyl alcohol, or a surface of the non-woven fabric strip can be subjected to plasma treating, in order to improve the liquid-passing property when using the filter cartridge for filtering a water-based liquid.

In the present invention, a heat bonding method is preferred as a method for bonding fiber intersections for preparing the non-woven fabric from the thermoplastic fiber. The method includes a thermal compression bonding method by means of an apparatus such as a thermal embossing roll and a heat flat calender roll; and a method using a heat treating machine of a hot blast-circulating type, a heat through-air type, an infrared heater type or a vertical hot blast-

blowing type. Among them, a method using a thermal embossing roll is preferred, because it can elevate a production rate of a non-woven fabric, provides a good productivity and can reduce a cost.

As shown in Fig. 7, a non-woven fabric produced by the method using a thermal embossing roll has part 8 where strong thermal compression bonding by an embossing pattern is applied and part 9 where only weak thermal compression bonding by deviating from an embossing pattern is applied. This makes it possible to trap a lot of foreign matters 2 in the part 8, and a part of the foreign matters in the part 9, while the remaining foreign matters can pass through the long fiber non-woven fabric to move to the following layer. Preferred is this deep layer-filtering structure, in which even the inside of the filter is utilized. In this case, an embossing patterned area is preferably from 5 to 25%. Setting the lower limit of this area to 5% can enhance the filtering effect exerted by the part 8 and 9, and setting the upper limit to 25% can control the rigidity of the non-woven fabric not to become too high. Further, a part of foreign matters are allowed to pass through the non-woven fabric strip.

A composite fiber comprising a low melting resin and a high melting resin, wherein the melting point difference is 10°C or more, preferably 15°C or more, is preferred as the fiber constituting the non-woven fabric strip. The melting point difference of 10°C or more

stabilizes a heat adhesion property in the fiber intersections of the non-woven fabric. In the case of a resin having no melting point, the flow-starting temperature is defined as a melting point. Stabilized heat adhesion in the fiber intersections of non-woven fabric strips will allow less particles which have been trapped in the vicinity of the fiber intersections to flow out of filter cartridges, when a filtering pressure and a flow amount of a solution are elevated, and will result in a less deformation of the filter cartridge. Further, even if a substance contained in a filtrate deteriorate the fibers, the stabilized heat adhesion can reduce probability of the fibers falling, and thus it is desirable.

The composite fiber described above may be in any forms such as a parallel type and a sheath-core type, wherein a low-melting resin is present on at least a part of a fiber surface.

A combination of the low melting resin and the high melting resin in the composite fibers shall not specifically be restricted as long as the melting point difference is 10°C or more, preferably 15°C or more, which includes linear low density polyethylene/polypropylene, high density polyethylene/polypropylene, low density polyethylene/polypropylene, copolymer of propylene with other α-olefin/polypropylene, linear low density polyethylene/high density polyethylene, low density polyethylene/high density polyethylene, various

polyethylenes/thermoplastic polyester, polypropylene/ thermoplastic polyester, copolymerized low melting thermoplastic polyester/thermoplastic polyester, various polyethylenes/nylon 6, polypropylene/nylon 6, nylon 6/nylon 66 and nylon 6/thermoplastic polyester. Among them, a combination of linear low density polyethylene/polypropylene is preferably used, since rigidity and a void rate of the non-woven fabric strip can readily be controlled during a step of adhesion of fiber intersections in producing the non-woven fabric. When a filter cartridge is used for filtering a solution of a relatively high temperature, a combination of low melting polyester/polyethylene terephthalate can suitably be used, the polyester being prepared by copolymerizing with isophthalic acid.

In the present invention, other fibers than the thermoplastic fibers may be contained in the non-woven fabric strip as long as the effect of the present invention is not damaged. Examples of the fibers other than the thermoplastic fibers include rayon, cupra, cotton, hemp, pulp and carbon fiber. The content of the thermoplastic fiber may preferably be at least 30% by weight, and it can be 100% by weight. If it is less than 30% by weight, a strength of the non-woven fabric is reduced when thermally bonded by a thermal compression bonding method and a through-air heat treating method, so that the fibers are liable to fall off and to be mixed in the filtrate while filtering.

For preparing the non-woven fabric strip used for the filter cartridge of the present invention, a non-woven fabric-producing set-up, for example, a spinning width may be controlled to directly prepare the non-woven fabric strip, but preferably, a wide non-woven fabric is slit into strips.

A width of the non-woven fabric strip used for the filter cartridge of the present invention is preferably 0.5 to 40 cm. If this width is less than 0.5 cm, the wide non-woven fabric is likely to be broken when the non-woven fabric is slit into strips, and it is difficult to control a tension in winding around a perforated cylinder in a twill form. Further, when preparing a filter cartridge having the same void rate, the winding time is extended and the productivity is reduced. On the other hand, if the width exceeds 40 cm, a friction in a yarn passage of a winder including a traverse guide may be larger or the converged non-woven fabrics may be irregular in size.

A basis weight of the non-woven fabric strip, i.e., a weight per unit area of the non-woven fabric is preferably 5 to 200 g/m^2. If the value is smaller than 5 g/m^2, an amount of the fiber is reduced, resulting in an increased unevenness in the non-woven fabric or a reduced strength of the non-woven fabric, or occasionally difficulty in thermal bonding of the fiber intersections. On the other hand, the value larger than 200 g/m^2 will render the rigidity of the non-woven fabric too much increased, so that

the fabric is difficult to wind around a perforated cylinder in a twill form at the later stage.

An upper limit of a width of the non-woven fabric strip varies depending on the basis weight, and a product of a width (cm) and a basis weight (g/m^2) of the non-woven fabric strip is preferably 10 to 200 $cm \cdot g/m^2$. The value larger than 200 will render the rigidity of the non-woven fabric excessively increased, so that winding of the non-woven fabric on a perforated cylinder in a twill form becomes difficult at the later stage. Further, the non-woven fabric becomes too thick in converging, so that it becomes difficult to wind it densely. On the other hand, if the product is less than 10, the non-woven fabric may be cut.

In the present invention, an airflow amount ($cm^3/cm^2/sec$) of the non-woven fabric strip measured by JIS L 1096-A (1990) method varies depending on uses of the filter cartridge, and it is preferably 1 to 6000 $cm^3/cm^2/sec$.

In the present invention, a thickness of the non-woven fabric strip is 0.02 to 1.20 mm, preferably 0.05 to 0.90 mm. If a thickness of the non-woven fabric strip is less than 0.02 mm, a strength of the non-woven fabric is reduced, and the non-woven fabric may be cut when wound around a perforated cylinder in producing a filter cartridge. On the other hand, if a thickness of the non-woven fabric strip exceeds 1.20 mm, the rigidity may become

too high, so that the non-woven fabric is difficult to be wound around a perforated cylinder densely in a twill form.

The non-woven fabric strip is wound and processed into a form of a filter cartridge by the method mentioned above. This may be used for a filter cartridge as it is, or a gasket of foamed polyethylene having a thickness of approx. 3 mm may be stuck on an end surface of the filter cartridge to improve an adhesion property to housing.

In the filter cartridge of the present invention, divided fibers can also be used for the fibers of the non-woven fabric strip. However, since it is actually difficult to evenly divide fibers into divided fibers, a melt blown non-woven fabric having a similar average fiber diameter is more preferably used as described above.

When the non-woven fabric strip is made hydrophilic by incorporating a hydrophilic resin such as polyvinyl alcohol into a raw material resin for the fabric or subjecting the surface thereof to plasma treatment, the liquid-passing property of the resulting filter cartridge can be enhanced in case of filtering an aqueous solution. Accordingly, a filter cartridge using such resin is preferred for filtering an aqueous solution.

In the present invention, the filter cartridge thus prepared has a void rate preferably in a range of 65 to 85%. The value smaller than 65% will render the fiber density too high, so that the liquid-passing property is reduced. On the contrary, the value larger than 85% will

render the strength of the filter cartridge reduced and often cause deformation of the filter cartridge unfavorably when a high filtering pressure is applied.

The liquid-passing property can be improved by providing the non-woven fabric strip with notch or by perforating it. In this case, the number of the notch is preferably 5 to 100 per 10 cm of the non-woven fabric, and the perforation area is preferably 10 to 80%. The filtering performance can be controlled by winding plural non-woven fabric strips, or winding it together with other yarns such as a spun yarn. A wide non-woven fabric may be wound in a layer form while winding the non-woven fabric strip in a traversing manner, whereby the maximum flow-out diameter of particles can be controlled when a filter cartridge having a rough accuracy is prepared.

The filter life can be improved by winding a non-woven fabric having a high fineness in an internal layer of the filter cartridge and then winding a non-woven fabric having a low fineness in an external layer thereof. In this case, a fineness of the external layer is set suitably 2 to 8 times as low as that of the internal layer. Further, the filter life can be improved as well by winding a non-woven fabric having a wide slit width for the internal layer and winding a non-woven fabric having a narrow slit width for the external layer. In this case, a non-woven fabric strip width of the internal layer is set suitably 1.5 to 10 times as large as that of the external layer. Other methods for

improving the filter life include a method of winding a non-woven fabric having a large basis weight for the internal layer and then winding a non-woven fabric having a small basis weight for the external layer, and a method of winding a weakly twisted non-woven fabric for the internal layer and then winding a strongly twisted non-woven fabric for the external layer. It is suitable to set a basis weight of the non-woven fabric in the internal layer 2 to 10 times as large as that of the external layer and to set a twist of the non-woven fabric in the external layer 2 to 10 times as much as that of the internal layer. A dense and rough structure of the filter cartridge can be formed by these methods, and a filter life of the filter cartridge is improved.

In the present invention, an end face of the filter cartridge may preferably be smoothened by heat adhesion, which forms smooth end-sealing parts at both ends of the filter cartridge and elevates the sealing property. The non-woven fabric strip constituting both end parts of the filter cartridge is molten by heat, a solvent, a supersonic wave, etc. and then solidified while forming the smooth end faces. Since the non-woven fabric strip comprising the thermoplastic fiber is used in the present invention, a heating method is preferred.

Examples

The present invention shall be explained below in detail with reference to examples and comparative examples, but the present invention shall not be restricted to these examples. In the respective examples, the physical properties and the filtering performances of the filters were evaluated by the methods described below.

Winder and winding number

A winder had a traverse width (width of traversing) of 250 mm, in which a hole of a traverse guide 5 shown in Fig. 6 had a diameter of 5 mm. An initial speed of a bobbin was set up to 1500 rpm. A winding number (W), that is, a number of winding the non-woven fabric strip around a perforated cylinder from one end to the other end was controlled by interlocking a reciprocating motion of the traverse guide with a rotary motion of the perforated cylinder by means of several gears having an appropriate number of gear teeth.

Basis weight and thickness of non-woven fabric

The non-woven fabric having the area of 625 cm^2 (Examples 1 to 15 and Comparative Examples 1 to 5) or 500 cm^2 (Examples 16 to 25 and Comparative Examples 6 to 9) was cut off and weighed. The weight was converted to a weight per square meter to define a basis weight. Further, the thickness of the cut non-woven fabric was measured optionally at 10 points, (Examples 1 to 15 and Comparative Examples 1 to 5) or 12 points (Examples 16 to 25 and Comparative Examples 6 to 9), and the values of 8 points

(Examples 1 to 15 and Comparative Examples 1 to 5) or 10 points (Examples 16 to 25 and Comparative Examples 6 to 9) excluding the maximum value and the minimum value were averaged to define the thickness of the non-woven fabric. The thickness at the respective points was measured on the conditions of a load of 196 Pa and a measuring speed of 2 mm/sec by means of "Digithickness Tester (trade name)" manufactured by Toyo Seiki Seisaku-Sho, Ltd.

Fiber diameter of fiber constituting non-woven fabric

The non-woven fabric was sampled at 5 spots at random, and they were photographed through a scanning type electron microscope. 20 fibers per spot were selected at random to measure the diameters of the fibers, and an average value thereof was defined as the fiber diameter (μm) of the non-woven fabric.

Airflow amount

Measured according to JIS L 1096-A (1990) method. When the airflow amount exceeded 790 $cm^3/cm^2/sec$, a measured area of the test sample was reduced.

Void rate of filter material for filter cartridge

The major diameter, the minor diameter, the length and the weight of the filter cartridge were measured to determine the void rate using the following equation. In order to determine the void rate of the filter material itself excluding a perforated cylinder, the major diameter of the perforated cylinder was used for the value of the minor diameter, and a value obtained by deducting the weight

of the perforated cylinder from the weight of the filter cartridge was used for the value of the weight:

(Apparent volume of filter material) = {(Major diameter of filter material)^2 - (Minor diameter of filter material)^2} / 4 × π × (Length of filter material);

(Real volume of filter material) = (Weight of filter material) / (Density of raw material of filter material);

(Void rate of filter material) = {1 - (Real volume of filter material) / (Apparent volume of filter material)} × 100 (%).

<u>Initial trapped particle diameter, initial pressure loss and filter life</u>

One filter cartridge was mounted to a housing of a circulating type testing machine for filtering performance, and water was passed to circulate, controlling a flow rate to 30 dm^3/minute by means of a pump. A difference in pressures at the inlet and outlet of the filter cartridge was set as an initial pressure loss. Next, a cake prepared by mixing 8 kinds of testing powder I prescribed in JIS Z 8901 (1995) (abbreviated as JIS 8 kinds; intermediate diameter: 6.6. to 8.6 μm) with 7 kinds of the same powder (abbreviated as JIS 7 kinds; intermediate diameter: 27 to 31 μm) in a weight ratio of 1:1 was continuously added at 0.4 g/minute, (Examples 1 to 15 and Comparative Examples 1 to 5), or the JIS 7 kinds were continuously added at 0.2 g/minute (Examples 16 to 25 and Comparative Examples 6 to 9), and the original solution and the filtrate were sampled

5 minutes after starting of the addition. They were diluted to appropriate concentrations, and then the numbers of particles contained in the respective solutions were measured by means of a light shielding type particle detector to calculate an initial trapping efficiency. Further, the value thereof was interpolated to determine a particle diameter showing a trapping efficiency of 80%. The addition of the cake was still continued until the pressure loss of the filter cartridge reached to 0.2 MPa, and the original solution and the filtrate were again sampled to determine a trapped particle diameter. Time consumed from starting addition of the cake until reaching to 0.2 MPa was defined as a filter life. When the pressure difference did not reach to 0.2 MPa even the filter life reached to 1000 minutes, the measurement was discontinued at that point of time.

Bubbling and fiber falling of initial filtrate

One filter cartridge was mounted to a housing of a circulating type testing machine for filtering performance, and ion-exchanged water was passed, controlling a flow rate to 10000 cm^3/minute by means of a pump. 1000 cm^3 of an initial filtrate was sampled, and 25 cm^3 thereof was taken into a colorimetric bottle and stirred vigorously to observe bubbling 10 seconds after stopping the stirring. When a volume of bubble (volume from a liquid surface up to the top of bubble) was 10 cm^3 or more, it was judged poor and shown by a symbol "C"; when a volume of bubble was less than 10

cm^3, it was judged fair and shown by a symbol "B"; and when less than 5 bubbles having a diameter of 1 mm or more were observed, it was judged good and shown by a symbol "A". Further, 500 cm^3 of the initial filtrate was passed through a nitrocellulose filter having a pore diameter of 0.8 μm to judge fiber falling. When the number of fibers having a length of 1 mm or more per cm^2 of the filter paper were 4 or more, it was judged poor and shown by "C"; the number of 1 to 3 was judged fair and was shown by "B"; and the number of 0 was judged good and shown by "A".

Deformation of filter cartridge

One filter cartridge was mounted to a housing (transparent) of a circulating type testing machine for filtering performance, and water was passed to circulate, controlling a flow rate to 30 dm^3/minute by means of a pump. An appearance of the filter cartridge was photographed. The JIS 7 kinds were added until the pressure loss before and after the housing reached 0.5 MPa. Then, an appearance of the filter cartridge was photographed on the same conditions (object distance, magnification, etc.) when the pressure loss before and after the housing reached 0.5 MPa. The major diameter of the filter cartridges shown in the two photographs was measured by image analysis to determine a shrinkage percentage. A shrinkage less than 10% was judged good and shown by "A"; a shrinkage 10% or more and less than 20% was judged fair and shown by "B" and a shrinkage 20% or more was judged poor and shown by "C".

Example 1

Used as a non-woven fabric was a polypropylene melt blown non-woven fabric having a basis weight of 50 g/m^2, a thickness of 0.8 mm and a fiber diameter of 82 μm, in which fiber intersections were thermally bonded by remaining heat of spinning and an airflow amount was 1400 $cm^3/cm^2/sec$. Used for a perforated cylinder was a polypropylene injection-molded article having a minor diameter of 30 mm, a major diameter of 34 mm and a length of 250 mm, and also having 180 holes of 6 mm square. The above melt blown non-woven fabric was slit to a width of 2.5 cm to obtain a non-woven fabric strip. The strip was passed through a traverse hole of the winder to be converged and wound around the perforated cylinder with a winding number set to 4.429 until the major diameter reached to 62 mm to obtain a cylindrical filter cartridge 7 as shown in Fig. 8.

Example 2

A cylindrical filter cartridge was obtained in the same manner as in Example 1, except that used as a non-woven fabric was a polypropylene melt blown non-woven fabric having a basis weight of 20 g/m^2, a thickness of 0.2 mm and a fiber diameter of 3 μm, in which fiber intersections were thermally bonded by remaining heat of spinning and an airflow amount was 38 $cm^3/cm^2/sec$. This filter cartridge had a higher filtering accuracy than that of the filter cartridge described in Example 1.

Example 3

Used as a non-woven fabric were the same polypropylene melt blown non-woven fabric as in Example 2 and a polypropylene spun bonded long fiber non-woven fabric having a basis weight of 20 g/m^2, a thickness of 0.2 mm, a fiber diameter of 18 μm and an airflow amount of 560 cm^3/cm^2/sec. One melt blown non-woven fabric and one spun bonded long fiber non-woven fabric each described above were superposed and the fiber intersections were thermal compression bonded by means of a heat embossing roll at a heat bonded area rate of 13% to prepare a laminated non-woven fabric. A cylindrical filter cartridge was obtained in the same manner as in Example 1, except that this non-woven fabric was used to prepare a non-woven fabric strip having a width of 5 cm. This filter cartridge had almost the same filtering accuracy and an excellent filter life as compared with the filter cartridge described in Example 2.

Example 4

Used as a non-woven fabric was a polypropylene spun bonded long fiber non-woven fabric having a basis weight of 20 g/m^2, a thickness of 0.19 mm and a fiber diameter of 18 μm, in which fiber intersections were thermal compression bonded by means of a heat embossing roll at a heat bonded area rate of 13% and an airflow amount was 490 cm^3/cm^2/sec. The same perforated cylinder as in Example 1 was used. The spun bonded long fiber non-woven fabric was slit to a width of 5 cm to obtain a non-woven fabric strip. The strip was not converged and wound around the perforated

cylinder by means of a winder with a winding number set to 4.429 until the major diameter reached to 62 mm to obtain a cylindrical filter cartridge.

Example 5

The same non-woven fabric strip and perforated cylinder as in Example 1 were used. The non-woven fabric strip was passed through a traverse hole of a winder and converged. It was wound around the perforated cylinder on the same conditions as in Example 4 to obtain a filter cartridge. This filter cartridge had a lower filtering accuracy, a better liquid-passing property and a longer filter life than those of the filter cartridge described in Example 4.

Example 6

A cylindrical filter cartridge was obtained in the same manner as in Example 5, except for changing the raw material resin of the spun bonded long fiber non-woven fabric to polyethylene terephthalate. This filter cartridge showed almost the same filtering performance as that of the filter cartridge described in Example 5.

Example 7

A cylindrical filter cartridge was obtained in the same manner as in Example 5, except for changing the raw material resin of the spun bonded long fiber non-woven fabric to nylon 66. This filter cartridge showed almost the same filtering performance as that of the filter cartridge described in Example 5.

Example 8

A cylindrical filter cartridge was obtained in the same manner as in Example 5, except that sheath-core type composite fibers comprising high density polyethylene as a low melting component and polypropylene as a high melting component in a weight ratio of 5:5 were used as the structural fibers for the spun bonded long fiber non-woven fabric. This filter cartridge had a more excellent accuracy than that of the filter cartridge described in Example 5 and showed such an excellent stability in the filtering accuracy that the trapped particle diameter at 0.2 MPa scarcely changed from the initial trapped particle diameter.

Example 9

A cylindrical filter cartridge was obtained in the same manner as in Example 8, except that linear low density polyethylene was used as the low melting component for the sheath-core type composite fiber. This filter cartridge had almost the same filtering accuracy as that of the filter cartridge obtained in Example 8 and had a more excellent liquid-passing property than that of the filter cartridge described in Example 8.

Example 10

A cylindrical filter cartridge was obtained in the same manner as in Example 9, except that the thermal bonding method for the fiber intersections was changed from the thermal compression bonding method by a hot embossing roll to a heat treating method by a hot blast-circulating type

heating apparatus. This filter cartridge had a little lower filtering accuracy than that of the filter cartridge described in Example 9.

Example 11

A cylindrical filter cartridge was obtained in the same manner as in Example 5, except that the long fiber non-woven fabric was slit to a width of 1 cm and that the winding number was changed to 3.476. This filter cartridge showed almost the same performance as that of the filter cartridge described in Example 5. However, time required for winding was longer than in Example 2.

Example 12

A cylindrical filter cartridge was obtained in the same manner as in Example 11, except that the long fiber non-woven fabric was slit to a width of 9 cm and that the winding number was changed to 3.714. This filter cartridge had a lower filtering accuracy than that of the filter cartridge described in Example 11, and this may be because the non-woven fabric strip-converged matter became extremely thick.

Example 13

A cylindrical filter cartridge was obtained in the same manner as in Example 5, except that a fiber diameter of the fiber constituting the non-woven fabric strip was changed to 40 μm. This filter cartridge had a lower filtering accuracy than that of the filter cartridge described in Example 5.

Example 14

A cylindrical filter cartridge was obtained in the same manner as in Example 5, except that a basis weight of the non-woven fabric strip was changed to 44 g/m^2. This filter cartridge had a lower filtering accuracy than that of the filter cartridge described in Example 5.

Example 15

A cylindrical filter cartridge was obtained in the same manner as in Example 5, except that the non-woven fabric strip was twisted 100 times per one meter instead of converging. This filter cartridge showed almost the same filtering performance as that of the filter cartridge described in Example 12.

Comparative Example 1

A cylindrical filter cartridge was obtained in the same manner as in Example 2, except that polypropylene spun yarns having a diameter of 2 mm prepared by spinning fibers having a fiber diameter of 22 μm was used in place of the non-woven fabric strip. This filter cartridge had an initial trapped particle diameter larger than that of the filter cartridge described in Example 5 and almost the same as that of the filter cartridge described in Example 12. However, it had an inferior liquid-passing property and a shorter filter life than those of the filter cartridge described in Example 12. Further, bubbling was observed in the initial filtrate, and falling of the filter material was observed as well.

Comparative Example 2

A cylindrical filter cartridge was obtained in the same manner as in Example 2, except that a filter paper No. 1 prescribed in JIS P 3801 (1995), which was cut to a width of 5 cm, was used in place of the non-woven fabric strip. This filter cartridge had an initial trapped particle diameter smaller than that of the filter cartridge described in Example 5, but the trapped particle diameter at an elevated pressure was changed from the initial one to a large extent. Further, the filter life was extremely short, and falling of the filter material was observed in the initial filtrate.

Comparative Example 3

Short fibers comprising polypropylene and high density polyethylene which were dividable to eight parts and had a fiber diameter of 25 μm were webbed by means of a carding machine, and the webbed matter was subjected to fiber division and fiber entanglement by high pressure water processing to obtain a divided short fiber non-woven fabric having a basis weight of 22 g/m^2. This non-woven fabric was observed under an electron microscope to carry out image analysis, which showed that 50% by weight of the whole fibers was divided into a fiber diameter of 9 μm. A cylindrical filter cartridge was obtained in the same manner as in Example 5, except that this non-woven fabric was cut to a width of 5 cm and used in place of the non-woven fabric strip. An initial trapped particle diameter in this filter

cartridge was smaller than that in the filter cartridge described in Example 5, but a trapped particle diameter at 0.2 MPa was larger. Further, a little bubbling in the initial filtrate was observed as well as falling of the fibers.

Comparative Example 4

A cylindrical filter cartridge was obtained in the same manner as in Example 11, except that used as a non-woven fabric was a polypropylene melt blown non-woven fabric having a basis weight of 100 g/m^2, a thickness of 1.5 mm and a fiber diameter of 140 μm, in which fiber intersections were thermally bonded by remaining heat of spinning and an airflow amount was 1400 $cm^3/cm^2/sec$. It was difficult to wind the non-woven fabric densely around the perforated cylinder so that the filtering accuracy could not be measured.

Comparative Example 5

A cylindrical filter cartridge was obtained in the same manner as in Example 11, except that used as a non-woven fabric was a polypropylene melt blown non-woven fabric having a basis weight of 140 g/m^2, a thickness of 0.5 mm and a fiber diameter of 90 μm, in which fiber intersections were thermally bonded by remaining heat of spinning and an airflow amount was 600 $cm^3/cm^2/sec$. It was difficult to wind the non-woven fabric densely around the perforated cylinder as was the case with Comparative Example 4 so that the filtering accuracy could not be measured.

Comparative Example 6

Used as a non-woven fabric was a polypropylene spun bonded long fiber non-woven fabric having a basis weight of 90 g/m^2, a thickness of 0.80 mm and a fiber diameter of 80 μm, in which fiber intersections were thermally bonded by a heat embossing roll at a heat bonded area rate of 13% and an airflow amount was 1000 $cm^3/cm^2/sec$. This spun bonded long fiber non-woven fabric was slit into a non-woven fabric strip having a width of 5 cm. The same perforated cylinder as in Example 1 was used. The strip was passed through a traverse hole of the winder to be converged and wound around the perforated cylinder with a winding number set to 4.429 until the major diameter reached to 62 mm to obtain a cylindrical filter cartridge as shown in Fig. 8. In this case, neither equation (A) nor equation (B) was satisfied. As compared with the filter cartridge of Example 4 which had such a high filtering accuracy that an initial trapped particle diameter was 7 μm, this filter cartridge had an initial trapped particle diameter of 103 μm, which proved that it could not trap fine particles.

Comparative Example 7

Used as a non-woven fabric was a polypropylene spun bonded long fiber non-woven fabric having a basis weight of 50 g/m^2, a thickness of 0.86 mm and a fiber diameter of 500 μm, in which fiber intersections were thermally bonded by a heat embossing roll at a heat bonded area rate of 13% and an airflow amount was 3000 $cm^3/cm^2/sec$.

This spun bonded long fiber non-woven fabric was slit into a non-woven fabric strip having a width of 5 cm. The same perforated cylinder as in Example 1 was used. The strip was passed through a traverse hole of the winder to be converged and wound around the perforated cylinder with a winding number set to 4.429 until the major diameter reached to 62 mm to obtain a cylindrical filter cartridge as shown in Fig. 8. In this case, neither equation (A) nor equation (B) was satisfied. As compared with the filter cartridge of Example 4 which had such a high filtering accuracy that an initial trapped particle diameter was 7 μm, this filter cartridge had an initial trapped particle diameter of 349 μm, which proved that it could not trap fine particles.

Table 1

	Example 1	Example 2	Example 3	Example 4	Example 5
Non-woven fabric strip					
Raw material of fiber*1	PP	PP	PP	PP	PP
Fiber diameter µm	82	3	18 & 3	18	18
Production process	Melt blow	Melt blow	S + M*2	Spun bonding	Spun bonding
Method for bonding fiber intersections	Remaining heat	Remaining heat	Embossing	Embossing	Embossing
Basis weight g/m^2	50	20	40	20	20
Width cm	2.5	5	5	5	5
Thickness mm	0.8	0.2	0.35	0.19	0.19
Airflow amount $cm^3/cm^2/sec$	1400	38	35	490	490
Fitness of equation (A)	A	A	A	A	A
Filter cartridge					
Processing of non-woven fabric	Converging	Converging	Converging	None	Converging
Void rate of filter material %	78	80	81	77	81
Initial trapped particle diameter µm	80	8	8	7	13
Initial pressure loss MPa	0.001	0.025	0.025	0.013	0.003
Trapped particle diameter in 0.2 MPa µm	80	9	9	8	14
Filter life min.	>1000	20	30	70	215
Bubbling	A	A	A	A	A
Fiber falling	A	A	A	A	A

*1: Raw material for sheath/core in the case of composite fiber

*2: Lamination of spun bonded non-woven fabric and melt blown non-woven fabric

Table 1 (Cont'd)

	Example 6	Example 7	Example 8	Example 9	Example 10
Non-woven fabric strip					
Raw material of fiber*1	PET	Nylon 66	HDPE/PP	LLDPE/PP	LLDPE/PP
Fiber diameter μm	15	16	18	18	18
Production process	Spun bonding	Spun bonding	Spun bonding	Spun bonding	Spun bonding
Method for bonding fiber intersections	Embossing	Embossing	Embossing	Embossing	Hot-air circulating
Basis weight g/m^2	20	20	20	20	20
Width cm	5	5	5	5	5
Thickness mm	0.27	0.23	0.19	0.19	0.19
Airflow amount $cm^3/cm^2/sec$	600	580	470	470	450
Fitness of equation (A)	A	A	A	A	A
Filter cartridge					
Processing of non-woven fabric	Converging	Converging	Converging	Converging	Converging
Void rate of filter material %	81	81	80	80	81
Initial trapped particle diameter μm	13	13	12	12	13
Initial pressure loss MPa	0.002	0.002	0.003	0.002	0.001
Trapped particle diameter in 0.2 MPa μm	14	14	12	12	13
Filter life min.	210	210	220	220	240
Bubbling	A	A	A	A	A
Fiber falling	A	A	A	A	A

*1: Raw material for sheath/core in the case of composite fiber

Table 2

	Example				
	11	12	13	14	15
Non-woven fabric strip					
Raw material of fiber*1	PP	PP	PP	PP	PP
Fiber diameter μm	18	18	40	18	18
Production process	Spun bonding	Spun bonding	Spun bonding	Spun bonding	Spun bonding
Method for bonding fiber intersections	Embossing	Embossing	Embossing	Embossing	Embossing
Basis weight g/m^2	20	20	20	44	20
Width cm	1	9	5	2.5	5
Thickness mm	0.19	0.19	0.19	0.39	0.19
Airflow amount $cm^3/cm^2/sec$	490	490	780	260	490
Fitness of equation (A)	A	A	A	A	A
Filter cartridge					
Processing of non-woven fabric	Converging	Converging	Converging	Converging	Converging
Void rate of filter material %	80	82	82	80	80
Initial trapped particle diameter μm	12	18	30	17	13
Initial pressure loss MPa	0.003	0.003	0.001	0.003	0.003
Trapped particle diameter in 0.2 MPa μm	13	19	30	18	14
Filter life min.	210	630	>1000	620	210
Bubbling	A	A	A	A	A
Fiber falling	A	A	A	A	A

*1: Raw material for sheath/core in the case of composite fiber

Table 2 (Cont'd)

	Comparative Example				
	1	2	3	4	5
Non-woven fabric strip	(Spun yarn)	(Filter paper)			
Raw material of fiber[*1]	PP	Cellulose	HDPE/PP	PP	PP
Fiber diameter μm	-	-	9	140	90
Production process	-	-	(Fiber confounding)	Melt blow	Melt blow
Method for bonding fiber intersections	-	-	(High pressure water)	Remaining heat	Remaining heat
Basis weight g/m^2	-	90	22	100	140
Width cm	-	1.5	5	1	1
Thickness mm	-	0.2	0.2	1.5	0.5
Airflow amount $cm^3/cm^2/sec$	-	-	150	1400	600
Fitness of equation (A)	-	-	A	C	C
Filter cartridge					
Processing of non-woven fabric	-	None	None	Converging	Converging
Void rate of filter material %	76	72	77	-	-
Initial trapped particle diameter μm	18	11	10	-	-
Initial pressure loss MPa	0.005	0.022	0.010	-	-
Trapped particle diameter in 0.2 MPa μm	22	20	13	-	-
Filter life min.	280	30	80	-	-
Bubbling	C	A	B	-	-
Fiber falling	C	C	C	-	-

*1: Raw material for sheath/core in the case of composite fiber

Example 16

Used as a non-woven fabric was a polypropylene long fiber non-woven fabric obtained by a spun bonding method. The fiber intersections were thermally bonded by a thermal compression bonding method by means of a heat embossing roll. The non-woven fabric had a basis weight of 22 g/m^2, a thickness of 200 μm and an average fiber diameter of 17 μm. The long fiber non-woven fabric was slit to a width of 50 mm to prepare a non-woven fabric strip. Further, used for a perforated cylinder was a polypropylene injection-molded article having a minor diameter 30 mm, a major diameter of 34 mm and a length of 250 mm, and also having 180 holes of 6 mm square. A winding number (W) of a winder was set up to 3.1875 (M_2 in the equation (3) is 8 in this case). The non-woven fabric strip was passed through a hole of a traverse guide in the winder and converged, and it was wound around the perforated cylinder until a major diameter reached to 60 mm to obtain a cylindrical filter cartridge. Both end faces thereof were welded by heating for 5 seconds by means of a hot plate having a surface temperature of 175°C to obtain a cylindrical filter cartridge as shown in Fig. 8. Neither bubbling nor falling of the filter material was observed and the pressure loss was small, and thus, the filter cartridge was proved excellent.

Examples 17 to 21

Cylindrical filter cartridges were obtained in the same manner using the same non-woven fabric strip and perforated cylinder as in Example 16, except that the winding numbers (W) were set to 3.2778 (Example 17), 3.2917 (Example 18), 3.3847 (Example 19), 3.4118 (Example 20) and 3.1885 (Example 21), respectively. When the 2-fold values (2W) of these winding numbers (W) are approximated to fractions having denominators (M_2) of two figures or less, the denominators are 9, 12, 13, 17 and 61, respectively. As these filter cartridges had larger M_2, the initial trapped particle diameters became smaller. Accordingly, the value of M_2 correlates with the initial trapped particle diameter. When 2W are approximated to fractions having denominators (M_3) of three figures or less, the initial trapped particle diameter does not decrease in proportion to the denominator (M_3). For example, M_3 is larger in Example 20 than in Example 21, but the initial trapped particle diameter is smaller in Example 21. Thus, it proves that M_3 in the equation (3) does not correlate with the filtering accuracy. The winding number W is smaller in Example 20 than in Example 21, but the initial trapped particle diameter is smaller in Example 21. Thus, it proves that the initial trapped particle diameter does not increase in proportion to the winding number W. The filter described in Example 21 had a relatively large pressure loss and a little poor liquid-passing property as compared with the other filters.

Examples 22 and 23

Cylindrical filter cartridges were obtained in the same manner as in Example 19, except that a width of the non-woven fabric strip was changed to 2 cm (Example 22) or 3 cm (Example 23). These filter cartridges had large initial trapped particle diameters as compared with that of the filter cartridge described in Example 19.

Example 24

A cylindrical filter cartridge was obtained in the same manner as in Example 19, except that used as a non-woven fabric strip was a melt blown non-woven fabric having an average fiber diameter of 2 μm, a basis weight of 22 g/m^2 and a width of 5 cm. This filter cartridge had a small initial trapped particle diameter as compared with that of the filter cartridge described in Example 19.

Example 25

A cylindrical filter cartridge was obtained on the same conditions as in Example 19, except that used as a non-woven fabric strip was a laminated non-woven fabric obtained by thermal compression bonding by means of a heat embossing roll, which comprised three kinds of non-woven fabrics: a polypropylene long fiber non-woven fabric having a basis weight of 5 g/m^2 and a fineness of 2 dtex which was obtained by a spun bonding method, a melt blown non-woven fabric having an average fiber diameter of 2 μm, a basis weight of 22 g/m^2 and a width of 5 cm, and a polypropylene long fiber non-woven fabric having a basis weight of 5 g/m^2 and a fineness of 2 dtex which was obtained by the spun bonding

method. This filter cartridge had a small initial trapped particle diameter as compared with that of the filter cartridge described in Example 19.

Comparative Example 8

A polypropylene short fiber having a fineness of 2 dtex, a cut length of 51 mm and a crimp number of 14 was formed by conventional melt spinning, and it was spun to obtain a spun yarn. The spun yarn was wound around the same perforated cylinder as in Example 16 with a winding number (W) set to 3.2252 to obtain a filter cartridge. Both end faces thereof were welded by heating for 5 seconds by means of a hot plate having a surface temperature of 175°C to obtain a filter cartridge. This filter cartridge was uneven on the end face and inferior in a sealing property of the end face. The initial trapped particle diameter thereof was in-between of the initial trapped particle diameters in Examples 19 and 20, but it had a larger pressure loss than those of both Examples 19 and 20 and an inferior liquid-passing property. Further, bubbling and the fibers fallen off the filter material were observed in the filtrate, and therefore, it was not preferred as a filter cartridge.

Comparative Example 9

A filter cartridge was obtained in the same manner using the same materials as in Example 16, except that the winding number (W) was changed to 0.6538. The wound non-woven fabric strip was liable to come off this filter cartridge, and it was not suited for a filter cartridge.

Comparative Example 10

A filter cartridge was obtained in the same manner using the same materials as in Example 16, except that the winding number (W) was changed to 10.1923. The wound non-woven fabric strip was liable to come off this filter cartridge, and it was not suited for a filter cartridge.

Comparative Example 11

Used as a structural fiber for the non-woven fabric strip were short fibers comprising polypropylene and high density polyethylene which were dividable into eight parts in a fiber cross section and had a fineness of 2 dtex and a fiber length of 64 mm. This dividable short fiber was webbed by processing by means of a carding machine, and the webbed matter was processed by means of a heat embossing roll to prepare a non-woven fabric. The non-woven fabric was treated twice by means of a water jet apparatus to divide the fiber into a divided non-woven fabric having a basis weight of 22 g/m^2 and a thickness of 210 μm. The non-woven fabric was slit to a width of 50 mm to prepare a non-woven fabric strip. Further, a winding number (W) of a winder was set up to 3.1875 (M_2 in the equation (3) is 8 in this case). The non-woven fabric strip was passed through a hole of a traverse guide in the winder and converged, and it was wound around a perforated cylinder until a major diameter reached to 60 mm to obtain a cylindrical filter cartridge. Both end faces thereof were welded by heating for 5 seconds by means of a hot plate having a surface

temperature of 175°C to obtain a filter cartridge. The filter cartridge thus obtained had a little reduced filtering accuracy as compared with Example 16. A little bubbling and falling of the filter material were observed in the filtrate, and the pressure loss was large. Further, the filter cartridge was liable to be deformed, and it was judged that its use needs a lot of attention in case of the large pressure.

Comparative Example 12

Used as a non-woven fabric was the same polypropylene spun bonded long fiber non-woven fabric as in Example 16. This fabric was slit into a non-woven fabric strip having a width of 5 cm. The same perforated cylinder as in Example 16 was used. The strip was passed through a hole of a traverse guide in the winder to be converged and wound around a perforated cylinder with a winder number set to 0.8077 until a major diameter reached to 62 mm to obtain a cylindrical filter cartridge as shown in Fig. 8. As compared with the filter cartridge of Example 16 having an initial trapped particle diameter of 59 μm, this filter cartridge had an initial trapped particle diameter of 300 μm, which proved that it could not trap fine particles.

Comparative Example 13

Used as a non-woven fabric was the same polypropylene spun bonded long fiber non-woven fabric as in Example 16. This fabric was slit into a non-woven fabric strip having a width of 5 cm. The same perforated cylinder

as in Example 16 was used. The strip was passed through a hole of a traverse guide in the winder to be converged and wound around a perforated cylinder with a winder number set to 10.0381 until a major diameter reached to 62 mm to obtain a cylindrical filter cartridge as shown in Fig. 8. As compared with the cartridge filter of Example 16 having a initial trapped particle diameter of 59 μm, this cartridge filter has a initial trapped particle diameter of 500 μm, which proved that it could not trap fine particles.

Table 3

	W	Approximation of 2W with denominator of two figures	M_2	Approximation of 2W with denominator of three figures	M_3	Non-woven fabric	Width cm	Basis weight g/cm^2
Example 16	3.1875	6 and 3/8	8	6 and 3/8	8	S	5	22
Example 17	3.2778	6 and 5/9	9	6 and 5/9	9	S	5	22
Example 18	3.2917	6 and 7/12	12	6 and 7/12	12	S	5	15
Example 19	3.3847	6 and 10/13	13	6 and 347/451	451	S	5	22
Example 20	3.4118	6 and 14/17	17	6 and 691/839	839	S	5	22
Example 21	3.1885	6 and 23/61	61	6 and 118/313	313	S	5	22
Example 22	3.3847	6 and 10/13	13	6 and 347/451	451	S	2	22
Example 23	3.3847	6 and 10/13	13	6 and 347/451	451	S	3	22
Example 24	3.3847	6 and 10/13	13	6 and 347/451	451	M	5	22
Example 25	3.3847	6 and 10/13	13	6 and 347/451	451	SMS	5	32
Comparative Example 8	3.2252	6 and 9/20	13	6 and 168/373	373	Spun yarn	0.3	-
Comparative Example 9	0.6538	1 and 4/13	13	1 and 255/829	829	S	5	22
Comparative Example 10	10.1923	20 and 5/13	13	20 and 5/13	13	S	5	22
Comparative Example 11	3.1875	6 and 3/8	8	6 and 3/8	8	Divided yarn	5	22

S : Spun bonded non-woven fabric

M : Melt blown non-woven fabric

SMS: Spun bonded non-woven fabric/melt blown non-woven fabric/spun bonded non-woven fabric

Table 3 (Cont'd)

	Width × basis weight cm × g/cm^2	Void rate %	80% trapped particle diameter µm	Pressure loss MPa	Bubbling	Falling of filter material	Deformation
Example 16	110	85	59	0.003	A	A	A
Example 17	110	82	39	0.004	A	A	A
Example 18	75	76	8.3	0.018	A	A	A
Example 19	110	81	27	0.006	A	A	A
Example 20	110	76	7.5	0.020	A	A	A
Example 21	110	74	5	0.030	A	A	A
Example 22	44	81	28	0.005	A	A	A
Example 23	66	78	17	0.009	A	A	A
Example 24	110	81	20	0.006	A	A	A
Example 25	160	81	20	0.006	A	A	A
Comparative Example 8	-	70	10	0.030	C	C	B
Comparative Example 9	110	-	-	-	-	-	-
Comparative Example 10	110	-	-	-	-	-	-
Comparative Example 11	110	85	50	0.004	B	B	C

Effects of the Invention

The filter cartridge of the present invention has a high filtering accuracy, a long filter life and a good liquid-passing property, in which an initial trapped particle diameter little changes, a pressure loss is small and neither bubbling nor falling of the filter material is observed, as compared with a conventional bobbin winder type filter cartridge.